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The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

Groundwater

Investigating groundwater resources in the North West province

The Water Research Commission (WRC) funded investigations into the groundwater potential in fractured crystalline rocks of the North West province.

Background

The assessment of groundwater quality and quantity is a major step towards ensuring the sustainable use and management of one of the most basic needs of human being. Understanding the amount of groundwater resource and its quality assists in creating awareness amongst decision makers to use, manage and to protect groundwater without adversely affecting its future demand.

In this study, investigation of groundwater potential in crystalline basement rocks of the North West Province was carried out. The area of study is located in the Naledi Local Municipality; situated in the central part of the North West Province. It covers an area of ~7260 km^2 and consists of 8 Quaternary catchments.

Hydrogeologically, a large part of the area falls within the Lower Vaal catchment. The average annual precipitation in the area is ~350 mm and temperature varies from very cold (below freezing point) to 35^0 C during the warm seasons. Groundwater recharge in the area is low (<10 mm) and largely depends on temperature and the seasonality and intensity of rainfall.

Potential evaporation rate ranges from 1960 mm to 2100 mm per annum, exceeding annual rainfall. It is typically a semi-arid to arid region, and groundwater is the main source of water supply for domestic and agricultural use.

Several groundwater studies have been carried out previously by private and government organizations aimed at development of rural and municipal water supply. Most of these studies were mainly focused around Vryburg and Stella, Dithakwaneng, Huhudi and Lima that are located within the Municipality.

In the previous studies, aquifer test, recharge estimation, geophysical and geological logging were carried out at number of sites.

Determining groundwater potential

In general, groundwater potential depends on many hydrogeological factors including surface and bedrock lithology, structures, slope steepness and morphology, stream density, climate, soil and land use.

Although the previous studies contributed significantly to the background information about the groundwater potential of the area, however, the influence of different hydrogeological features was not well addressed in light of understanding the groundwater potential of the area.

The main objectives of this study were therefore:

- To delineate groundwater potential zones using multivariate statistical modeling approaches.
- To assess groundwater controlling factors.
- To investigate the groundwater quality using hydrochemical data and environmental isotopes.

Understanding the groundwater potential of the area is useful to regulate and optimise water use without adversely impacting water resource for future use. This briefing note presents a summary of the findings of the present work.

Main findings

Aquifer tests were carried out at three boreholes to determine sustainable yield and aquifer parameters. Based on analysis of the data, borehole management and abstraction recommendation were provided for each of the boreholes.

The analysis of hydrochemical data show the presence of fresh water throughout the study area with the exception of some boreholes located around Stella and north of Vryburg. The exceptions are due to elevated concentrations of chloride, nitrate, fluoride and total hardness that exceeded the standard concentrations as prescribed by SANS241.

The water types in the study area are largely influenced by rock-water interaction and anthropogenic sources. The influence of high evaporation in the northern part of the area also partly contributed to chloride-dominated water-type.

The enrichment in the stable isotopic composition ($\delta^{2}H$ and $\delta^{18}O$) of groundwater indicates the effect of evaporation which is consistent with high chloride content as shown using analysis of hydrochemical data. However, the limited isotope data used in the present study makes difficult to understand the interaction between surface water and groundwater.

Two multivariate statistical modeling were carried out to map the most prospective areas for groundwater occurrence. These include empirical (data–driven) and conceptual (knowledge-based) approaches.

The data-driven approach includes artificial neural networks (ANNs), Weights of Evidence (WofE), Logistic Regression (LG) and Principal Component Analysis (PCA). The Knowledge-based modeling involves fuzzy logic (FL) and fuzzy clustering (FC).

Both statistical modeling approaches were applied to five evidential themes that include; geology, lineaments, geomorphology/slope, land use and soil texture.

For the data-driven modeling approach, 46 boreholes with yield > 10 ℓ/s and 43 sites with no indication of groundwater occurrence (barren sites) were used as training points.

The 5 evidential themes and the training data were used as an input to ***feed-forward radial basisfunction*** neural network training algorithm. Various statistical analysis were carried out that include; analysis of model sensitivity, training, validation and testing. These allowed to generate groundwater potential map of the area.

The resulting map shows a number of groundwater potential zones varying from "***very good***" to "***very poor***". The zone shown as '***very good***' and '***good***' groundwater potential covers ~17% and ~22% of the study area, respectively. The superimposed borehole yield also confirms the results derived from multivariate statistical modeling approaches, whereby high borehole yields (> 15 l/s) fall within carbonate rocks consisting of dolomite and limestonelocated in the southern part of the area. In addition, follow-up geophysical surveys carried out at selected sites confirmed the presence of conductive layers varying in depth from 20 m to 35 m.

The high conductivity possibly indicates the presence of water-bearing formation, in particular dolomite located around Vryburg and highly fractured granite just south of Stella. The high yielding wellfields can be attributed to dissolution of carbonate rocks by water that percolates through pre-existing fractures leading to enlarged fracture apertures, and consequently resulting in the development of large cavities that can store and supply significant amount of water (e.g. Armoedsvlakte and Swrtfontein wellfields located north of Vryburg).

The WofE, PCA, RBFLN and LG provided nearly similar results showing lithologic units and fracture connectivity and concentrationare the main controlling factors of groundwater occurrence. The influence of lithology is significant in the southern part of the area, while fracture connectivity played important role in controlling groundwater occurrence within the hard rocks terrane consisting of the Ventersdorp volcanic rocks, Archaean granite gneisses and the greenstone belt.

The multivariate statistical approaches used for characterization of groundwater potential in crystalline basement and carbonate rocks of the study area is very effective in delineating potential areas. Differences in fracture set populations, coupled with contrast in primary permeability of various rock types significantly contributed to variability in groundwater potential throughout the study area.

Although high groundwater potential zones are primarily associated with carbonate rocks, the results derived from calculation of statistical correlation between lineaments density and borehole yield suggests that high yielding wellfields are largely controlled by fracture concentration within crystalline basement rocks.

Furthermore, the significant contrast in groundwater potential between the southern and northern parts of the area can be attributed to the presence of two end-members controlling the development of groundwater, i.e. dissolution channels in the south and fracture connectivity and density in the central and northern parts of the area.

Further reading:
To order the report, ***Assessment of groundwater potential in fractured hard rocks around Vryburg, North West Province, South Africa*** (**Report No. 2055/1/13),** contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.